

Representability of METT-TC Factors in JC3IEDM

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Abstract

Commanders require relevant information about background information in order to exercise effective command and control (C2). METT-TC factors (Mission, Enemy, Terrain & Weather, Troops, Time Available and Civil Considerations) represent the canonical, militarily significant background against which information is evaluated and military decisions are made. If this background is to be encoded, shared, and, ultimately, processed and reasoned about by computers or computer-assisted C2 systems, the METT-TC background must be represented in some standard format with a shared computer-processable semantics. The JC3IEDM (Joint Command, Control, and Consultation Information Exchange Data Model) represents several years of effort by NATO's Multinational Interoperability Programme at developing a representation of military situations in order to support communication and interoperability among NATO forces. All information to be shared by participants must, therefore, be representable within JC3IEDM. In this paper, we point out aspects of METT-TC that are not currently or not completely representable in JC3IEDM. These include aspects such as cover and concealment, fields of fire, and mission purpose. We end by suggesting ways in which JC3IEDM can be extended to represent these aspects of METT-TC factors.

1. Introduction: METT-TC Factors and Representability

Commanders require accurate, relevant, and timely information about the background factors at play on the battlefield, the so-called METT-TC factors (Mission, Enemy, Terrain & Weather, Troops, Time Available and Civilian Considerations), in order to make command and control decisions. If this background information is to be encoded, shared, and, ultimately, processed and reasoned about by computers or computer-assisted C2 systems, the METT-TC background must be represented in some standard format with a shared computer-processable semantics. Currently, the most widely adopted representation for sharing military information is the information exchange data model promulgated by the Multilateral Interoperability Programme of NATO, with participation by 26 countries. The standard is currently being used by several elements of the Department of Defense, coalition forces and commercial organizations. The US Marine Corps recently adopted JC3IEDM as a standard for data integration, for example [Allen, 2006].

METT-TC factors are descriptions of militarily relevant aspects of the environment or background upon which a military operation occurs. The accurate depiction of the environment in which military action occurs is necessary for good decision-making. Further, background information often informs how incoming data is to be interpreted. The military commander's view of the state of the battlespace is constructed from reports generated by both human and non-human sensors in the battlespace. In many cases (see for example the discussion in [Powell et al, 2006]), the import or credibility of what is being communicated by these reports is determined by the background information. Therefore, unless background conditions are accurately described, an accurate depiction of what is currently going on in the battlespace is not possible. As such, background information is not simply ancillary information in a military environment.

We employ the notion of 'background information' rather than 'context' here since the notion of context in information systems often involves a sense of un-shared perspective that we want to avoid [Stalnaker, 1999]. In context-aware representations, statements that are true in one context are not true in another (the house is to the left of the barn from the perspective of x but not of y) but may be translatable into true statements in another perspective ("the barn is to the right of the house"). Similarly, within the context of the Sherlock Holmes stories, "Holmes lived on Baker Street in London" is true, but that is not true within the context of an official London census of the time. There is no information about the background or environment that cannot be shared with respect to METT-TC factors or which requires translation in order to be true for different users. (Translation may of course be required to make the information usable by those with different linguistic backgrounds.) Background information can (and does) influence what can be inferred from a statement, however. With the background information "There is a severe backup on US Route 93 on the southbound lanes at Medford, MA", it can be inferred that the travel time from Winchester, MA to Boston's airport will take longer than the average travel time that could

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be predicted using the distance between the two points and the average speed of vehicles on Route 93 for that interval, for example. However, the fact encoded as background knowledge (“There is a backup on Route 93 south at time t ”) is true for all users.

In the rest of this paper, we examine to what extent all of the relevant aspects of background or environment of military operations can be represented within the framework of the JC3IEDM information exchange model.

2. Semantic Interoperability: JC3IEDM and Related Work

The Multilateral Interoperability Programme¹ (MIP) is a long-standing, NATO-supported program intended to foster international interoperability of Command and Control Information Systems (C2IS) through the development of standard data models and data exchange mechanisms. Significant joint coalition effort has gone into the development of the MIP data model, which was first released in the mid to late 1990’s as the Generic Hub (GH) Data Model. In subsequent years it became known as the Land Command and Control Information Exchange Data Model (LC2IEDM), followed by the Command and Control Information Exchange Data Model (C2IEDM) and now it exists as the Joint Command, Control and Consultation Information Exchange Data Model (JC3IEDM). The data model captures information about an impressive array of battlespace objects and features, their properties, and situations made up of facts about objects and activities involving collections of objects.

JC3IEDM, first published by the MIP in December, 2005², aims at encoding all of the relevant information about an arena of operations that commanders would need to share. As such, it is a very detailed and comprehensive data model. JC3IEDM allows the representation of the land, sea, and air as well as certain aspects of the communications infrastructure. It represents nearly all objects of interest including organizations, persons, equipment, facilities, geographic features, weather, capabilities, and military control measure such as boundaries. On the face of it, this model offers broad coverage of METT-TC factors. An updated version 3.1 was published in December, 2006.

While JC3IEDM is intended foremost for the exchange of command, control and communication information between information systems, it is increasingly gaining consideration as the basis for the general data models that underlie C3 information systems. A primary reason for this trend is the desire to leverage the great wealth of experience and knowledge that has gone into its development. JC3IEDM consists of 289 entities, 396 relationships between entities, 1729 entity attributes and nearly 7000 value codes. The MIP data model is updated on a regular (one might say “aggressive”) basis.³ Several projects currently envision using JC3IEDM as the basis for automatically encoding and exchanging battlespace information. The German *Sokrates*⁴ project, for example, is developing an automatic battlespace report analysis tool that uses a Protégé-encoded ontology based on C2IEDM to process reports and generate information to be added to both a database and to a map interface which represents the common operational picture. The Battlefield Management Language research program (BML, see below) and other project teams make a strong case for using the C2/JC3IEDM as a basis for ontologies for battlespace management

The upper-level entities in JC3IEDM are related according to the diagram in Figure 1. (In IDEFIX notation, the closed dot indicates that there may be many such entities in the relationship. An open dot means just one.)

¹<http://www.mip-site.org>

² http://mip-site.org/publicsite/Baseline_3.0/

³ We have made a translation of JC3IEDM into an OWL ontology freely available for others to use (<http://vistology.com/ont/2006/JC3IEDM3.0>). The translation was performed using the XML document that specifies the JC3IEDM 3.0 ERwin data model definition; due to the use of this XSD-defined document, other ERwin based data models can be translated into OWL using a similar strategy (and in many cases, the code) that we have described elsewhere [Matheus and Ulicny, 2006].

⁴ SOKRATES - Automatic Report Analysis project page. http://www.fgan.de/fkie/fkie_c41_f13_en.html

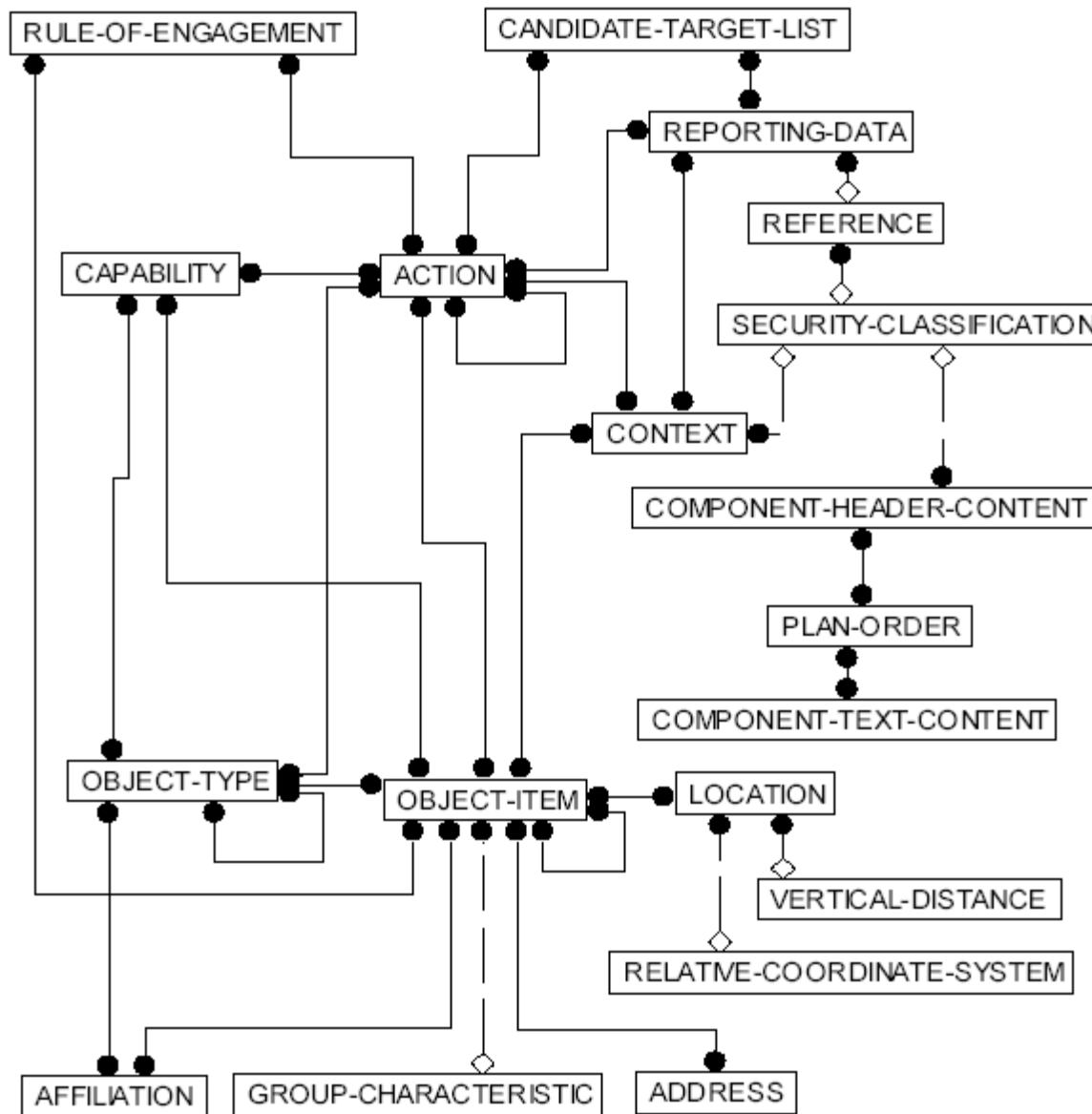


Figure 2. Independent Entities for Creating the Data Specification

Figure 1. Independent Entities for Creating the Data Specification

Figure 1 shows all of independent entities found at the highest level of the JC3IEDM along with the conceptual relationships between them; these relationships represent conceptual aggregates of finer relationships and additional entities found in the logical model. Some things to note:

- 1) Most of these Entities are sub-classed in the logical model and in some cases the hierarchy of classes can be relatively deep (i.e., greater than 3).
- 2) There are two object classes, OBJECT-TYPE and OBJECT-ITEM. OBJECT-TYPE is used for more static information associated with an entire class of objects (e.g., the track width of an Abrams Tank, its maximum speed, etc.) where as OBJECT-ITEM is used to capture information specific to individuals (e.g., the speed of a tank, the fact it has 5 gallons of gas). The original intended use of JC3IEDM and its precursors provide an explanation of this. JC3IEDM was intended to be a stable data model, the stability of which was guaranteed by its extensibility. For this reason, the designers chose a parallel hierarchy of types and instances of objects so that if a new type of tank was

introduced, for example, representing this fact would require simply adding another row to the EQUIPMENT-TYPE table and a row for each instance of a tank of that type to the OBJECT-ITEM tables. It would not require a new schema. The OBJECT-TYPE and OBJECT-ITEM hierarchies do not fully mirror each other, particularly deeper within the structures, but they are closely related (see Figure 2 below).

- 3) REPORTING-DATA represents pedigree information that is used extensively to identify when, from whom and how reliable/credible a specific piece of information is.

Significantly, there is an open-source XML Schema conversion tool that allows one to convert the published data model into an XML Schema at a variety of levels. One level is essentially just the serialization of the physical data representation in relational tables. There are then two flavors of Object-Oriented (OO) XML Schemata (XSD) conversions possible that allow for the representation of discrete battlespace facts with more or fewer constraints on the relations between items specified within the schemata itself. That is, one OO XML Schema allows essentially unconstrained associations between entities; the other provides ontology-based constraints on associations. The various schemata are described in ANNEX O. EXTENSIBL MARKUP LANGUAGE (XML) REFERENCE IMPLEMENTATIONS of the published standard.⁵

For our purposes, we have found it useful to represent messages in the format of OWL or RDF triples: subject-predicate-object, abstracting away from the use of true URIs as proxies for referents. This allows us to envision a future set of applications in which information about the battlespace would be reasoned about automatically within a logical representation derived from something like JC3IEDM or a successor representation rather than simply using JC3IEDM to enable sharing of a representation of the battlespace. The conversion of such a large and rich data model into a logical representation like OWL is a daunting task, but we have shown that it can be entirely done in an automated way [Matheus and Ulicny, 2006].

Unfortunately, because of the parallel OBJECT/OBJECT-TYPE hierarchies, in a direct translation to OWL from the JC3IEDM data model, this means that the directly translated OWL does not represent that a tank instance inherits the properties defined for that tank type directly. There is a type hierarchy and an instance hierarchy and they are connected by an entity of OBJECT-ITEM-TYPE. This makes such simple inferences impossible from within the context of OWL alone, given our current translation of JC3IEDM into OWL. Two possible solutions exist here: either rules can be provided that allow one to make such inferences on the basis of the automatically-translated OWL, or one could translate the JC3IEDM into OWL in a way that represents the semantics of the JC3IEDM model more transparently, perhaps taking the set of relations from the CIDOC-CRM model to relate JC3IEDM models in a more direct way. We make note of this difficulty here, although it does not play a central role in the discussion that follows.

⁵ http://www.mip-site.org/publicsite/Baseline_3.0/JC3IEDM-Joint_C3_Information_Exchange_Data_Model/JC3IEDM-Annex%20O-XML-UK-DMWG-Edition_3.0_2005-12-09.pdf

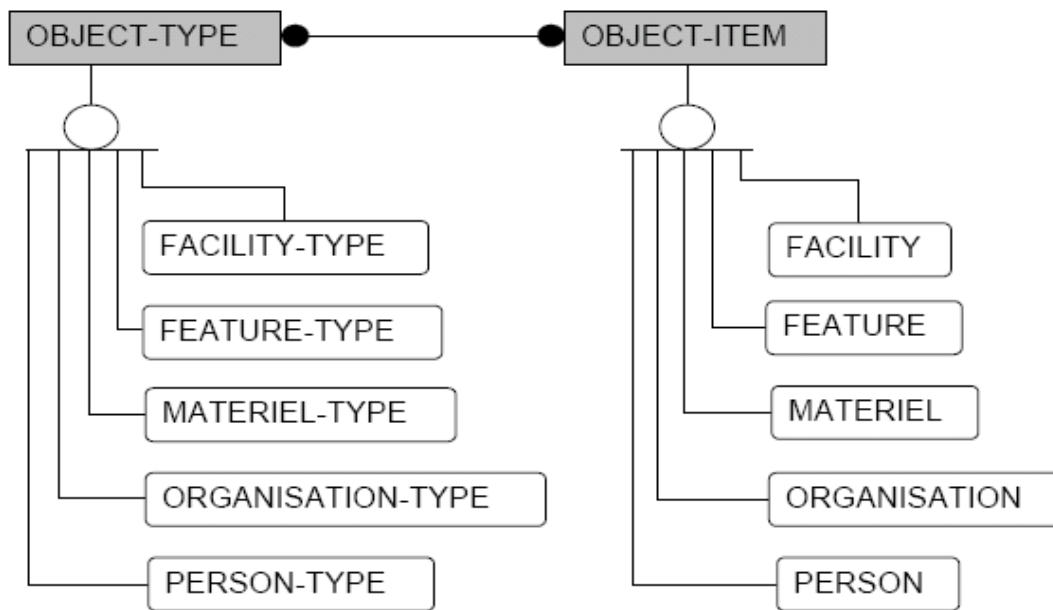


Figure 2 Conceptual relationship between OBJECT-TYPE and OBJECT-ITEM Entities

2.1. Related Initiatives and Research Programs

The Battlefield Management Language (BML) [Tolk et al, 2005] is a research program aimed at developing a collection of web-based services that is based on C2IEDM, a previous version of the JC3IEDM. BML is described as “an unambiguous language to command and control forces and equipment conducting military operations and to provide for situational awareness and a shared, common operational picture”. The first version of the CBML standard is available here (<http://www.sisostds.org/index.php?tg=fileman&idx=list&id=33&gr=Y&path=CBML+Standard+Version+I>). It is basically an extension of a subset of the C2IEDM model pertaining to actions and their participants necessary to capture military tasks.

The Mobility Common Operational Picture (M-COP) [Blais, 2005] defines architecture for web-based tools supporting battlespace operations. They discuss the need for an M-COP ontology which they expect to be built by importing ontologies from other groups, but have not yet announced further progress. M-COP is described as “A subset of the COP consisting of relevant tactical movement and maneuver data and information shared by more than one command. The M-COP can be tailored for various users and includes data and information for mobility of individual combatants, ground vehicles, and autonomous/robotic vehicles.”

A related initiative is the development of GeoBML [Stein, 2005] described as a system to “enable tactical terrain reasoning services for the range of BC systems and users that will match the level of abstraction with needs of BC as instantiated in the C2IEDM.” GeoBML will allow a “deeper-level of automated decision support to human and software users incorporating the dynamic environment.” GeoBML is a research project that is part of the Battlespace Terrain Reasoning and Awareness⁶ (BTRA) initiative of the Army Corps of Engineers.

The Military Scenario Definition Language (MSDL) [Franchesini et al, 2004] is being developed by the OneSAF Objective System (OOS) to provide simulations with a mechanism for loading Military Scenarios. As a standard, MSDL is not being developed for simulation alone. The intent is for MSDL to define Military Scenarios that are independent of the application of that scenario. To that end, MSDL is an XML-based data interchange format that enables C2 planning applications to interchange the military portions of scenarios with Simulations and other applications. The scope of MSDL is bounded by the situation at one instant in time combined with the COA about to be taken in context to that situation. The intent is for MSDL to include that information which is either Core or Common to the situation and course of action of a military scenario.

⁶ www.tec.army.mil/fact_sheet/BTRA.pdf. One product of the BTRA initiative is the FASST (Fast All-season Soil STrength) model that allows modelers to predict the effects of weather on terrain for trafficability.

3. Representing Mission in JC3IEDM

Mission characterizes a planned military operation within a specified period of time and with specific objectives. The Mission includes the Who, What, When, Where and Why of an ordered military action. Representation of the mission includes identifying the objective and specifying the essential and non-essential tasks of the operation. The Mission includes one or more tasks (What) and any constraints applicable in achieving those tasks (Rules of Engagement). Areas of interest (Where) for the mission are identified here. The When is specified as the time available for acting from a given start time. The overall purpose of the mission (Why) is specified.

In JC3IEDM, there is no entity that corresponds to a mission as a distinct entity over and above the tasks it comprises. A mission would therefore have be encoded as a set of ORDERED ACTION-TASKs with corresponding OBJECTIVES and RULES-OF-ENGAGEMENT with allotted start and end times. Named areas of interest are represented as a category of CONTROL-FEATURE.

RULES-OF-ENGAGEMENT are represented as text strings. The “why” of the mission is also only representable in terms of the intent-text associated with the ORGANISATION-ASSOCIATION, which specifies why a unit or other entity (“who”) is involved in the activity in the form of a text string. Unless these text strings are further decomposed into a logical representation, it would be impossible to reason about them automatically.

For example, to encode the following mission:

The 1st Unit of Employment (**who**) in the next 24 hours (**when**) is ordered to deploy to Atropia (**where**) to conduct an NEO of US personnel (**what**) in order to prepare for an invasion of Atropia.

Example 1: Representation of MISSION in JC3IEDM

```
<OWL>
  <ACTION-TASK-ORDER rdf:ID="ACT1">
    <name-text rdf:type="xsd:string">Atropia NEO</name-text>
    <is-focused-on>
      <ObjectiveList>
        <OID>AOI1</OID>
        <!-- The specific value that represents the class of ACTION-OBJECTIVE with
respect to item or type. -->
        <!-- A class of battlespace object (FACILITY-TYPE, FEATURE-TYPE, MATERIEL-TYPE,
ORGANISATION-TYPE or PERSON-TYPE) which is the focus of a specific ACTION. -->
        <category-code>OT</category-code>
        <qualifier-code>AUTH</qualifier-code>
        <priority-code>1</priority-code>
        <OBJECT-ITEM-TYPE>
          <object-type-id rdf:resource="OT16"/>
          <OBJECT-ITEM-TYPE>
        </ObjectiveList>
      </is-focused-on>
      <!-- Noncombatant Evacuation Operation -->
      <activity-code rdf:type="xsd:string">EVACT</activity-code>
      <!-- action to take place over next 24 hours -->
      <planned-start-datetime>20100801120000.000</planned-start-datetime>
      <planned-end-datetime>20100802120000.000</planned-end-datetime>
      <is-acted-upon-as-specified-by>
        <ORGANIZATION-ACTION-ASSOCIATION-Controls>
          <has-its-role-specified-through rdf:resource="OI57"/> <!-- = 1UE -->
          <effective-datetime>20100801120000.000</effective-datetime>
          <intent-text>
            The 1st Unit of Employment (UE) deploys to conduct the NEO with three
subordinate Units of Action (UA)
          </intent-text>
        </ORGANIZATION-ACTION-ASSOCIATION-Controls>
      </is-acted-upon-as-specified-by>
    </ACTION-TASK-ORDER>
  </OWL>
```

```

        </ORGANIZATION-ACTION-ASSOCIATION-Controls>
    </is-acted-upon-as-specified-by>
<is-geometrically-defined-through>
    <LOCATION rdf:resource="ATROPIA"/>
</is-geometrically-defined-through>
    <requires>
        <ACTION-RESOURCE-ITEM>
            <object-item-id rdf:resource="A1.3"/>
        </ACTION-RESOURCE-ITEM>
    </requires>
</ACTION-TASK-ORDER>
<UNIT rdf:ID="OI57">
    <name-text>1st Unit of Employment</name-text>
    <is-classified-as>
        <OBJECT-ITEM-TYPE>
            <object-type-id rdf:resource="OT57"/>
            <is-referenced-to rdf:resource="RPTD1"/>
        </OBJECT-ITEM-TYPE>
    </is-classified-as>
    <formal-abbreviated-name-text>
        1st Unit of Employment
    </formal-abbreviated-name-text>
</UNIT>
<UNIT-TYPE-Combat rdf:ID="OT57">
    <dummy-indicator-code rdf:type="xsd:string">NO</dummy-indicator-code>
    <name-text rdf:type="xsd:string">Inf Division</name-text>
    <command-function-indicator-code rdf:type="xsd:string">YES</command-function-
indicator-code>
    <service-code rdf:type="xsd:string">ARMY</service-code>
    <arm-category-code>INF</armc-ategory-code>
    <size-code>DIV</size-code>
</UNIT-TYPE-Combat>
<FACILITY rdf:ID="OI15">
    <name-text>Atropia</name-text>
    <is-classified-as>
        <OBJECT-ITEM-TYPE>
            <object-type-id rdf:resource="OT15"/>
            <is-referenced-to rdf:resource="RPTD1"/>
        </OBJECT-ITEM-TYPE>
    </is-classified-as>
    <is-geometrically-defined-through>
    <!-- location of city is location of action, not otherwise defined -->
    <LOCATION rdf:ID="ATROPIA"/>
    </is-geometrically-defined-through>
</FACILITY>
<FACILITY-TYPE-City rdf:ID="OT15"/>
    <PERSON-TYPE rdf:id="OT16">
        <person-type-category-code>CIV</person-type-category-code>
        <person-type-subcategory-code>NKN</person-type-subcategory-code>
        <has>
            <!-- A specification of a country or political entity to which membership or
allegiance may be ascribed. -->
            <AFFILIATION-GEOPOLITICAL rdf:id="USA">
                <affiliation-geopolitical-code>USA</affiliation-geopolitical-code>
            </AFFILIATION-GEOPOLITICAL>
        </has>
    </PERSON-TYPE>

```



```

<!-- just a dummy reporting data for all objectitems -->
<REPORTING-DATA-ABSOLUTE-TIMING rdf:ID="RPTD1">
  <credibility-code>RPTFCT</credibility-code>
  <reporting-datetime>20100810030000.000</reporting-datetime>
  <reporting-organisation-id rdf:resource="OI57"/>
</REPORTING-DATA-ABSOLUTE-TIMING>
</OWL>

```

It is possible to group several action-tasks together via a context element, but it is not possible to assign an objective to the context as a whole. Thus, while it is possible to assign an objective or purpose to the component tasks of a mission, it is not possible to assign an objective or purpose to the set of action-tasks taken together. This is analogous to being able to say that one boiled the noodles and heated the sauce in order to cook the spaghetti but not be able to say why one cooked the spaghetti (e.g. to provide dinner for the family).

JC3IEDM lacks some vocabulary that might be useful as well. The Military Scenario Definition Language (MSDL) group⁷, for example, employs the entire Army Universal Task List for its set of possible tasks. These include some activities such as “raid” that are not included in the JC3IEDM 3.0. The MSDL also allows the specification of triggering events for activities -- friendly events, enemy events, threat events, or movement events -- which are not possible in JC3IEDM representations of tasks. Decision points and triggering events are not explicitly representable in JC3IEDM.

4. Enemy

The METT-TC representation of the Enemy must be able to represent a complete assessment of the enemy's strength, including weapons and weapons range, composition and order of battle, boundaries between units and reinforcement potential, readiness for battle, location and mobility. Enemy doctrine has likely been assessed ahead of time and is available as mission background information. The analysis of the enemy -- in the context of other METT-TC factors such as terrain/weather and blue troops -- identifies possible avenues of approach and enemy courses of action.

An important aspect of the representation of the enemy is the representation of historical patterns of enemy activity even when those haven't been canonicalized as doctrines. For example, it would be important to aggregate the enemy's placing of IEDs along routes over time, by day of week and time of day, to facilitate route planning.

JC3IEDM is designed to allow a common representational format for enemy and friendly troops. The only difference is the `ObjectItemStatusHostilityCode`, which is HO for Hostiles, FR for Friendlys, and so on for other statuses of forces (e.g. suspect, neutral, unknown, etc.). Enemy actions are expressed in the same way as friendly Actions.

Weapons can be associated with forces at various structural levels. However, it is not possible to relate weapons with their ranges within JC3IEDM. Thus, it is not possible to represent or derive a field of fire from the location of enemy forces and the association of particular weapons with those forces.

Enemy courses of action (ECOA) are not representable except as planned enemy action-tasks. This is obviously a deficiency, since ECOAs should be represented as possible, not future, actions. In general, there is no way to represent logical modalities (possible/necessary, should/must) within JC3IEDM or within a straightforward transformation of JC3IEDM to a logical representation such as OWL. JC3IEDM's only concession to modality is the notion of CAPABILITY, which encodes the abilities of individual OBJECT-ITEMs and -TYPES. Thus, one can say that this particular object can do certain things, but one cannot represent that an event, situation or fact involving certain OBJECTs might happen, is likely to occur, cannot occur and so on.

Similarly, the representation of enemy doctrine (usually or normally such-and-such unit or unit type does x in a certain situation) within JC3IEDM again requires a notion of logical modality that is absent from JC3IEDM. At most, one could

represent that an enemy unit had done actions of a specified type at certain dates, but any representation of a norm or behavior is not possible.

5. Terrain and Weather

It must be possible to represent complete information on terrain including the location and properties of natural and artificial terrain features such as mountains, marshes, cliffs, and so on as well as cities, airfields, bridges, railroads, and ports, slope, elevation, soil conditions, and vegetation. It must be possible to represent the impact of these on vehicle and human movement rates, maintenance, tempo, trafficability, and maneuverability by various types of forces, as well as the impact on the ability to engage in combat. The five military aspects of terrain are:

- Observation and fields of fire.
- Cover and Concealment
- Obstacles.
- Key and decisive terrain.
- Avenues of approach.

As for weather, it must be possible to represent all aspects of current and projected weather and atmospheric conditions in a location as well as to record the effect of weather on terrain, troops and equipment as necessary

We have seen from the Mission that built environment features are represented in JC3IEDM as Facilities. Geographic features are represented as Feature(s). Atmospheric elements are represented as Meteorologic-Feature(s). The following, for example, shows a representation of a segment of Interstate 5 in San Diego within JC3IEDM.

```
<OWL>
<ROAD rdf:ID="ROAD1">
  <name-text rdf:type="xsd:string">INTERSTATE 5</name-text>
  <is-geometrically-defined-by>
    <LINE rdf:ID="LINE1">
  <is-defined-using>
    <LINEPOINTLIST>
      <rdf:Seq>
        <LINEPOINT rdf:ID="LP1">
          <linepoint-sequence-ordinal rdf:type="xsd:string">1<linepoint-sequence-
ordinal>
            <makes-reference-to>
              <CARTESIANPOINT rdf:ID="PT1">
                <cartesian-point-x-coordinate-dimension
rdf:type="xsd:string">6261916.50005901</cartesian-point-x-coordinate-dimension>
                <cartesian-point-y-coordinate-dimension
rdf:type="xsd:string">1911741.87236069</cartesian-point-y-coordinate-dimension>
                <cartesian-point-z-coordinate-dimension
rdf:type="xsd:string">0</cartesian-point-z-coordinate-dimension>
              </CARTESIANPOINT>
            </makes-reference-to>
          </LINEPOINT>
        <LINEPOINT rdf:ID="LP2">
          <linepoint-sequence-ordinal rdf:type="xsd:string">2<linepoint-sequence-
ordinal>
            <makes-reference-to>
              <CARTESIANPOINT rdf:ID="PT2">
                <cartesian-point-x-coordinate-dimension
rdf:type="xsd:string">6261424.50005855</cartesian-point-x-coordinate-dimension>
                <cartesian-point-y-coordinate-dimension
rdf:type="xsd:string">1912720.87216961</cartesian-point-y-coordinate-dimension>
                <cartesian-point-z-coordinate-dimension
rdf:type="xsd:string">0</cartesian-point-z-coordinate-dimension>
              </CARTESIANPOINT>
            </makes-reference-to>
          </LINEPOINT>
        </LINEPOINT>
      </rdf:Seq>
    </LINEPOINTLIST>
  </is-defined-using>
</LINE>
</is-geometrically-defined-by>
</ROAD>
```

```

    <LINEPOINT rdf:ID="LP3">
    </rdf:Seq>
    </LINEPOINTLIST>
    </is-defined-using>
    </LINE>
    </is-geometrically-defined-by>
</ROAD>
</OWL>

```

JC3IEDM represents Terrain in terms of Features and Facilities, which are Object-Items and have Object-Types, which have locations. Unfortunately, one cannot say that a Facility or Feature is the Location of an Action, only that the Action has a geographically specified location that is shared with a Facility (or overlaps with part of a facility). One can also use a dummy location to say (indirectly) that two facilities are co-located, for example to say that a field hospital is located in a church, the geolocation of which is not itself represented, for whatever reason.

JC3IEDM represents facilities (man-made features) at only a crude level of detail. One can only say that one of a prescribed set of JC3IEDM features is present at a location; one cannot describe it further according to sub-features. These can only be represented as features that happen to be collocated. To give another example: it is possible to specify that a sniper, for example, has a location that is the location of a particular building, but it is not possible to specify that the sniper is located at the third window from the left on the north side of the sixth floor of that building (cf. CityGML⁸).

At the level of vocabulary, the Terrain Common Data Model specifies more feature-specific parameters for describing natural features than JC3IEDM does. There are approximately 167 features in the TCDM that have associated descriptive parameters as opposed to the twenty or so features in JC3IEDM which have set parametric descriptions.

Weather features are represented in terms of JC3IEDM METEOROLOGIC-FEATURE, which are also OBJECT-ITEMS with locations. Other, non-localized aspects of weather (Moon, Sun, Wind, Nautical Twilight, Relative Humidity, Chance of Precipitation, General Visibility, Clouds, Fog, and Haze) do not really have specifiable locations, but can be associated with reports from a given location.

Of the five military aspects of terrain above, it is possible to represent, key terrain, and avenues of approach, but not obstacles, fields of fire or cover and concealment. Being an obstacle is a relative notion: x is an obstacle to some y. Few things are obstacles to everything. With respect to fields of fire, as we mentioned above, JC3IEDM does not allow for the representation of weapon ranges. If it did, fields of fire could be represented somewhat accurately as geometric areas with specified locations. Not all of the inferences one would like to draw from the current METT-TC conditions are purely symbolic or logical inferences. Some inferences could involve numeric computations. The Army's Battlespace Terrain Reasoning and Analysis project [Visone, 2005], for example, contains modules for inferring line-of-fire information from terrain data (you can't shoot from A to B if there is a mountain in the way), and the effects of weather on the navigability of terrain (a model predicts whether certain vehicles can pass over land given a set of parameters describing the recent weather).

Similarly, the notion of cover or concealment involves the inability for something to be seen by something else at a particular perspective. It is a relative notion. Something that serves as cover or concealment to observers in a plane (e.g. dense foliage) may not serve as cover or concealment to observers at the same level.

6. Troops

For friendly forces, it must be possible to represent the equipment and weaponry available, maintenance requirements, and fuel supplies. Readiness for the mission considers experience, morale, rest, and training. Capabilities include the mobility (based primarily on the equipment, maintenance, and fuel supplies), and intelligence and surveillance assets

In JC3IEDM, Troops are represented as an Organisation or Unit. Any instance of ORGANISATION may have an ORGANISATION-STRUCTURE for which ORGANISATION-STRUCTURE-DETAIL identifies all instances of OBJECT-ITEM-ASSOCIATION that pertain to the specific instance of ORGANISATION-STRUCTURE. ORGANISATIONS have associated CAPABILITIES and STATUSES as well as LOCATIONS. UNITS have associated EQUIPMENT and

⁸ CityGML is an XML schema based extension of GML to urban environments, including city furniture (lights, etc). It supports various increasingly detailed levels of description up to the description of building interiors.

MATERIEL. JC3IEDM allows for the representation of nearly every aspect of Troop METT-TC information required except those deficiencies noted under Enemy.

JC3IEDM does not allow the representation of the current formation (e.g. Column) of a Unit, unlike in MSDL.

7. Time

It must be possible to represent the time available for any military operation. It must also be possible to represent the temporal relations between events and actions in the battlespace, as well as associating reports with times.

JC3IEDM has a somewhat parallel temporal structure equivalent to its geographical or location structure. Thus, just as every object can be assigned a location in JC3IEDM via an OBJECT-ITEM-LOCATION, every action can be associated with a temporal interval via a parameter of an associated ACTION-TASK. Further, each report has an obligatory report time. Again, unlike with Location, events can be used to locate other events temporally through ACTION-TEMPORAL-ASSOCIATION. For example, it is possible to say that such-and-such occurred after the bombing of such-and-such facility. However, only specific events can be explicitly represented as being correlated in this way: one could not say that certain kinds of activities increased after a bombing on a certain date.

Additionally, it is not possible to associate artifacts with temporal periods in JC3IEDM only with specific temporal intervals. Thus, one cannot say that a particular structure is a Bronze Age structure or dates to Roman occupation of that area; time intervals with definite start and end dates are required, while these may be rather fuzzy for the temporal periods at issue.

8. Civil Considerations

It must be possible to represent the influence of manmade infrastructure, civilian institutions, and attitudes and activities of the civilian leaders, populations, and organizations within an area of operations on the conduct of military operations. Civil considerations comprise six characteristics:

- Areas
- Structures
- Capabilities
- Organizations
- People
- Events

Civil Considerations involve representing and paying proper consideration to local Areas, Structures, Capabilities, Organizations, People and Events. In JC3IEDM, Areas are represented as Locations, Structures as Facilities, Capabilities as Capabilities, and Organizations as Group-Organizations.

In order to represent the presence of a group of 72 healthy non-combatant civilians of various ages on the roof of a particular US consulate in JC3IEDM, one would say the following:

```
<OWL>
<OBJECT-ITEM rdf:id="G1">
  <is-associated-with>
    <OBJECT-ITEM-GROUP-ACCOUNT>
      <object-item-group-account-id rdf:resource="GA57"/>
      <is-referenced-to rdf:resource="RPTD2"/>
    </OBJECT-ITEM-GROUP-ACCOUNT>
  </is-associated-with>
  <is-geometrically-defined-by>
    <!-- Let's suppose this is the US Consulate -->
    <LOCATION rdf:resource="L58"/>
  </is-geometrically-defined-by>
</OBJECT-ITEM>
<OBJECT-ITEM-GROUP-ACCOUNT rdf:id="GA57">
  <name-text>Group of US Civilians on US consulate roof</name-text>
  <action-ref>ACT1</action-ref>
  <count>72</count>
  <is-the-count-of>
```

```

<PERSON-TYPE rdf:id="PT57">
  <person-type-category-code>CIV</person-type-category-code>
  <person-type-subcategory-code>NKN</person-type-subcategory-code>
  <has>
    <!-- A specification of a country or political entity to which membership or
allegiance may be ascribed. -->
    <AFFILIATION-GEOPOLITICAL rdf:id="USA">
      <affiliation-geopolitical-code>USA</affiliation-geopolitical-code>
    </AFFILIATION-GEOPOLITICAL>
  </has>
</PERSON-TYPE>
</is-the-count-of>
<qualifier-code>HEALTH</qualifier-code>
<is-enumerated-in>
  <OBJECT-ITEM-GROUP-ACCOUNT-DETAILS rdf:id="GAD57">
    <provides-categorization-for>
      <GROUP-CHARACTERISTIC rdf:id="GC57">
        <age-group-code>MXD</age-group-code>
        <GroupCharacteristic>
        </provides-categorization-for>
      </GROUP-CHARACTERISTIC>
    </OBJECT-ITEM-GROUP-ACCOUNT-DETAILS>
  </is-enumerated-in>
</OBJECT-ITEM-GROUP-ACCOUNT>
</OWL>

```

Notice that the count parameter is more precise than it might be reasonable to expect from a report: 72, not “between 50 and 100” or something else.

Every area (area of interest), structure, organization, and person can be associated with an ethnic, linguistic, political and religious affiliation. However, it is not possible to provide more specificity than that encoded in JC3IEDM affiliation codes. Thus, it is not possible to provide finer-grained affiliations of structures, areas, persons or groups with loyalties to particular leaders, tribes, sects or dialects than JC3IEDM produces. Category codes such as these cannot be extended via the mechanism of OBJECT-ITEM/OBJECT-TYPE discussed earlier.

The ACTION-EVENT entity seems mostly to have been envisioned as a way of encoding singular events. There is no concept within JC3IEDM of a recurring event type (such as a religious or civil holiday). Thus, there is no way to represent such recurring event types in JC3IEDM.

9. Negation in JC3IEDM

It is not possible to report negative facts in JC3IEDM. One cannot directly encode the statement that an event of a particular type did not occur; for example, that the (anticipated) invasion of a city by the enemy did not take place. At most, one can report the current state of the situation at issue, if this corresponds to the negation of the issue at hand. For example, one cannot say that a bridge was not destroyed. One can report, however, that the bridge is still standing. One cannot report that a hospital has not been evacuated. One can report that the number of patients is some non-zero number. When no such representation of the current state is possible (as with being non-invaded), the representation of negative facts is not possible.

On the other hand, it is possible to indirectly record a negative fact in JC3IEDM as a negative response to a REQUEST. So, one could record that the response to a request (did the enemy invade such-and-such location before time t?) is ‘No’. This makes reasoning within a logical representation derived from JC3IEDM more complicated than that envisioned in most automated reasoning systems.

10. Conclusion

Military applications making use of background information are increasingly converging on the JC3IEDM data model as the basis of representing military situations. Reasoning about the impact of background conditions on military command and control would require the translation of JC3IEDM (or a successor) into a logical representation. An automated translation of JC3IEDM into a suitable logical representation that correctly represents the underlying semantics seems to be possible.

However, much of the data representing background battlespace information is derived from M&S technologies that are concerned with representing data in two-dimensional formats. As a result, much of the data assigns properties to lines, points, and areas on a map, but it does not represent all of the facts that it would be necessary to reason about symbolically. For example, shape file data may tell us that a road consists of a line connecting various points, but it is necessary to abstract from this that the road connects two cities. Performing these kinds of data abstractions will be necessary for doing adequate reasoning about the effects of METT-TC factors on the interpretation of battlespace reports.

Finally, on the negative side, JC3IEDM lacks certain depths of vocabulary that other, more specific models have. For example, it does not provide as detailed a representation of as many geographic or built features as the US Army's Terrain Common Data Model (TCDM) or CityGML. In a logical framework like OWL, this could be remedied by simply extending the vocabulary through appropriate namespaces. But, more seriously, given its origins as a relational data model, it is not surprising that it is unclear how to represent certain things in JC3IEDM that would require quantification over events or conditional relationships between events. These include the representation of doctrines as quantifying over events (for example, that always or in most cases, if the enemy is doing such-and-such, they will do thus-and-so). At best, it would be possible to represent such information within JC3IEDM currently only as text strings that are immune to automatic reasoning. It would be necessary to embed an OWL translation of JC3IEDM within a modal logic to reason about these. Similarly, it is not clear how to represent conditional relationships such as 'dead zones' (if Unit U is positioned here, it cannot fire on Location L), nor conditional vulnerabilities (if Enemy Unit EU is attacked at location L, it will not be vulnerable to/unable to do XYZ).

These logical shortcomings, not merely the lack of certain vocabulary items, represent a more serious issue with respect to the usability of JC3IEDM or a successor within a system for automatically reasoning about background information with a shared semantics.

11. References

Military Field Manuals:

- FM 3.0 <http://www.globalsecurity.org/military/library/policy/army/fm/3-0/ch5.htm>
 Battle Command
- FM 6.0 Operations. Appendix B. "METT-TC Factors"
- FM 17-98 <http://www.globalsecurity.org/military/library/policy/army/fm/17-98> -
 Ch. 2 - Battle Command, Appendix A – Combat Orders, Appendix F – Risk Management
- FM 34-130 [FM 34-130, Intelligence Preparation of the Battlefield](#)
 Ch. 2 - Conducting Intelligence Preparation of the Battlefield
- FM 71-1 <http://www.globalsecurity.org/military/library/policy/army/fm/71-1>
 Ch. 2 – Battle Command
- Combat Leader's Guide <http://www.au.af.mil/au/awc/awcgate/army/clg.pdf>

Allen, Brig. Gen. George J. (2006). Testimony to US House Armed Services Committee Subcommittee on Terrorism, Unconventional Threats, and Capabilities. April 6, 2006.

Blais, C. (2005) Common Maneuver Networks (CMN) and Mobility Common Operational Picture (M-COP)
<https://www.movesinstitute.org/openhouse2005/presentations/Blais01.pdf>

E. Dorion, C. Matheus and M. Kokar, *Towards a Formal Ontology for Military Coalitions Operations*. In Proceedings of the 10th International Command & Control Research and Technology Symposium, McLean, VA, June 2005.

Derrick Franceschini, Robert Franceschini, Robert Burch, Russ Sherrett, Jeff Abbott, (2004). "Specifying Scenario Using the Military Scenario Definition Language", Fall 2004 SIW.

Matheus, C, and B. Ulicny. (2006). On the Automatic Generation of an OWL Ontology based on the Joint C3 Information Exchange Data Model" ms.

Gerald M. Powell, C. Matheus, M. Kokar and D. Lorenz, *Understanding the Role of Context in the Interpretation of Complex Battlespace Intelligence*. (Fusion06)

Andreas Tolk, Michael Hieb, Kevin Galvin, Lionel Khimeche, Mark Pullen. *Developing a Coalition Battle Management Language to facilitate Interoperability between Operation CIS and Simulations in support of Training and Mission Rehearsal*, 2005 International Command and Control Research and Technology Symposium: The Future of Command and Control. <http://www.dodccrp.org/events/2005/10th/papers/249.pdf>.

Salim K. Semy, Mary K. Pulvermacher, Leo J. Obrst, The MITRE Corporation, (2005). "Towards the Use of an Upper Ontology for U.S. Government and Military Domains: An Evaluation".
http://www.mitre.org/work/tech_papers/tech_papers_04/04_0603/index.html, updated December 2005.

Stalnaker, R. C. (1999). "On the representation of context", *Context and Content: Essays on Intentionality in Speech and Thought* (pp. 96-113). Oxford: Oxford University Press.

Stein, Michael C. (2005). Terrain Reasoning and a GeoBML. Presentation to MSDL Study Group.
<http://discussions.sisostds.org/file.asp?file=MSDL%5F09June05%5FAM%5FPresentations%5F1%2Epiz>

Tolk, A and CL Blais, "Taxonomies, Ontologies, and Battle Management Languages - Recommendations for the Coalition BML Study Group". Spring Simulation Interoperability Workshop San Diego, April 2005.

Visone, Daniel L. (2005). "Battlespace Terrain Reasoning and Awareness", Proceedings, 2005 ESRI International User Conference <http://gis.esri.com/library/userconf/proc05/papers/pap2493.pdf>